Search for Higgs in LeptoSusy models

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Disclaimer

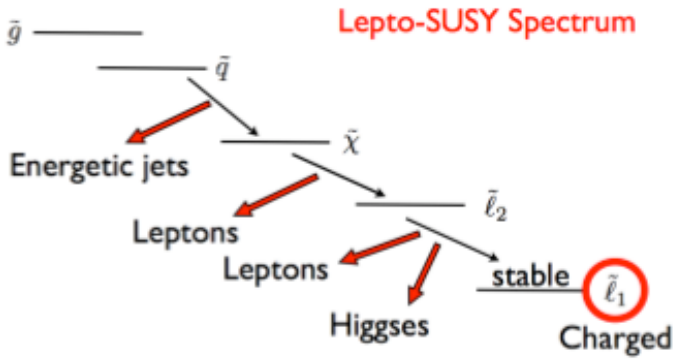
- This is really a report on trying to setup a complete analysis framework, starting from MC simulation of an exotic signal, understanding of the physics objects involved (AOD access) and setup of an analysis module to look at data (when and if they'll be available at higher energies)
- Many things are trivial, but achieving results is often a daunting task when using the ATLAS software..
- The bright side is to have a support center (ASC!) where to ask questions and initiate fruitful collaborations.
- This work is still very much in progress!

Outline

- The model
- Preliminary tests and validation
  - Parton level signature
- Current tests on fullSim vs fastSim
  - Lepton multiplicities
  - CHAMPS
  - B-tagging
- Plans for a signature based analysis
  - Using ANL InvMass framework

The model

- Leptogenic Supersymmetry
  - SUSY scenario characterized by cascade decays with copious lepton production;
  - Striking signatures that can be probed with just 200 pb^{-1} at LHC 10TeV
    - Long-lived sleptons
    - Several Isolated leptons
    - Energetic jets
    - No MET
    - Copious Higgs production…

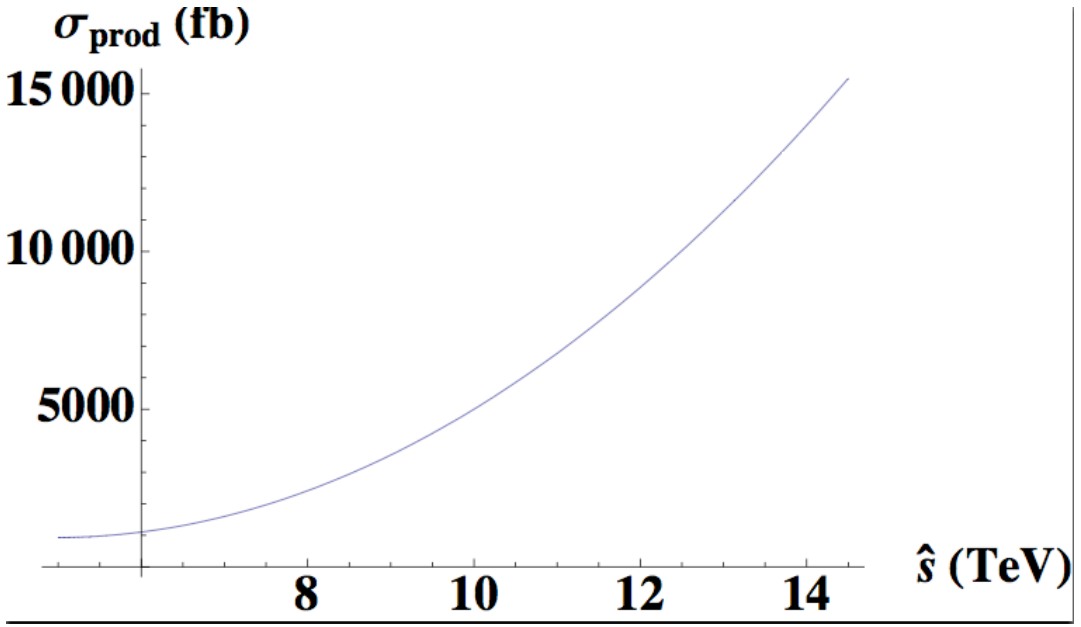


V.Sanz et al. Phys.Rev.D80:035010,2009.

The model (cont'd)

Input	m_3	2000 GeV		
	n_1	4.8		
	n_2	3.9		
	n_3	2.2		
	n_4	6.7		
	$\tan\beta$	10		
	sgnμ	+		
Output (GeV)	$m_{\tilde{g}}$	1938	$m_{\tilde{u}_L}$	949
	$m_{\tilde{\chi}_1^\pm}$	291	$m_{\tilde{u}_R}$	920
	$m_{\tilde{\chi}_2^\pm}$	676	$m_{\tilde{d}_L}$	952
	$m_{\tilde{\chi}_4^0}$	676	$m_{\tilde{d}_R}$	919
	$m_{\tilde{\chi}_3^0}$	353	$m_{\tilde{t}_1}$	920
	$m_{\tilde{\chi}_2^0}$	302	$m_{\tilde{t}_2}$	962
	$m_{\tilde{\chi}_1^0}$	271	$m_{\tilde{\ell}_L}$	248
	m_h	115	$m_{\tilde{\ell}_R}$	108
	$m_{H^\pm}$	387	$m_{\tilde{\nu}}$	236
	m_A	379	$m_{\tilde{\tau}_1}$	106
	m_{H_0}	379	$m_{\tilde{\tau}_2}$	249

Table 1: A sample spectrum calculated with SUSY-HIT.



At 7 TeV we expect ~ 100 events in 50pb^{-1}
At 10 TeV we expect ~250 events in 200pb^{-1}
No major sources of physics background
-- signal efficiency expected to be high

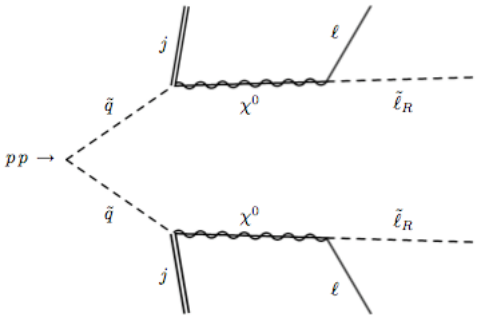
In this talk 10 TeV samples….

Final State topologies with no Higgs

Main Production mechanism: pair production of squarks $pp \to \tilde{q}\bar{\tilde{q}}\,, \tilde{q}\,\tilde{q}$

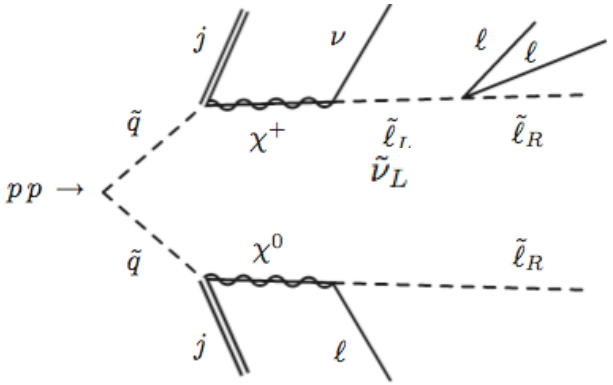
Four-Lepton Channels

Both gauginos decay to stable sleptons and leptons



Five-Lepton Channels

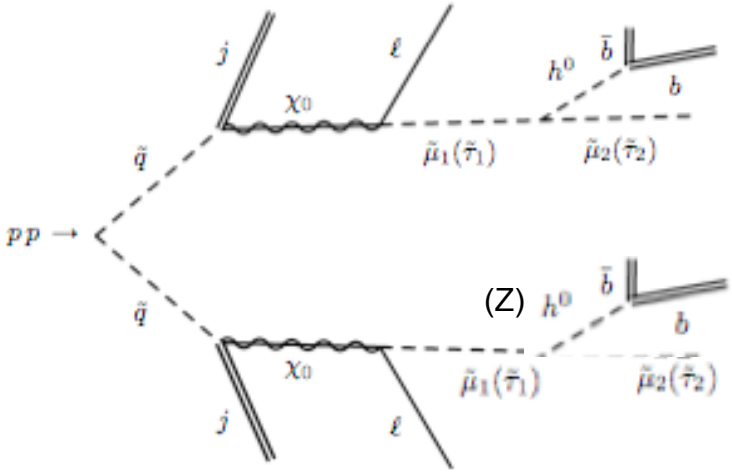
Long decay chain for charginos decaying to stable sleptons and leptons



Six-Leptons when combining the two above

Final states with Higgs

- The SM-Higgs boson in this scenario is light enough not to decay into WW;
- It decays predominantly into bbar (Br = 80%)
- Higgs is produced in cascade decays and it's free of most of the SM background
  - Clean bbbar invariant mass distribution study



$$\mathrm{BR}(\tilde{\mu}_1 \to h^0(Z) + \tilde{\mu}_2) = 44.1\%\,(35.1\%)$$
$$\mathrm{BR}(\tilde{\tau}_1 \to h^0(Z) + \tilde{\tau}_2) = 53.3\%\,(46.6\%)$$

Final State:
2 jets, 2 b-jets
2 leptons and
2 slowly moving sleptons

Sample

- Using a Madgraph file from Veronica Sanz, we generated events in the Athena environment and studied them at generator level and at jet level using the JetTruthCollection

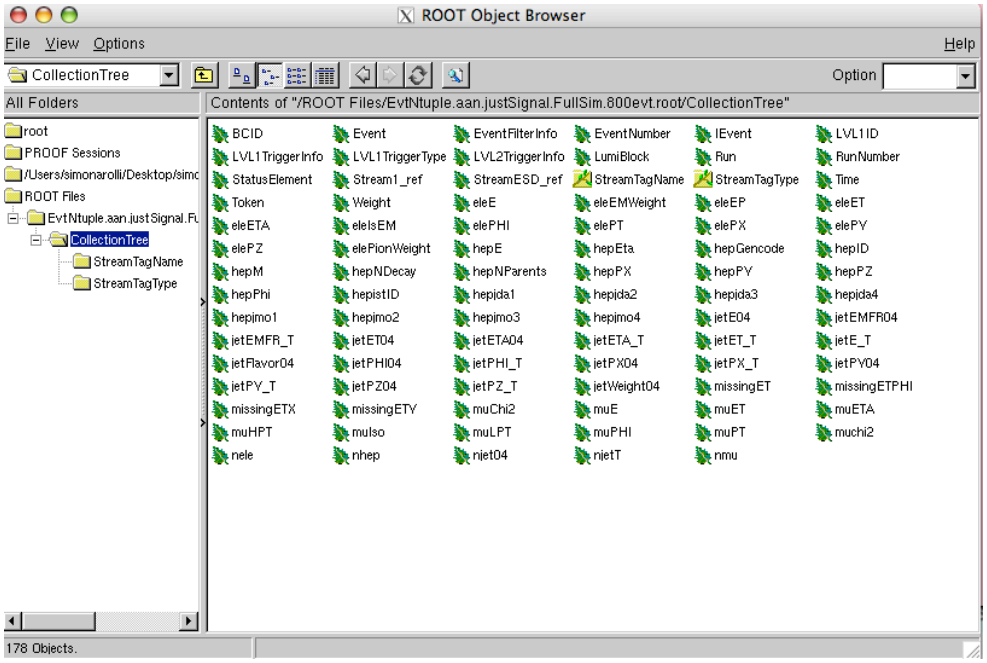
- These studies were considered necessary before submitting a request for a large sample through the central production service (request submitted in Dec 2009)

- Athena> csc_evgen08new_trf.py 000001 1 5000 1234 MC8.000001.MadGraphPythia.py test.root NONE NONE MadGraph.000001.test._00001.events.tar.gz NONE
  - Pythia only does PS, the generation of leptoSusy is left to Madgraph

- We analyzed two samples:
  - One with only Higgs production;
  - One with all processes (which is also the only physics background)

AOD Studies

- We used a customized ntuple (evtNtuple) which we derived from AnalysisSkeleton
  - Not very different than the DragonFly example
  - Easy to add information and decouple from the the athena framework
  - Easy to add information and learn on the way what AOD really contains….



AOD Studies

- Check leptons and sleptons multiplicity
- Check the Higgs mass reconstructed from the b-partons
  - Select b's and check for their mother
  - Select Higgs and check for its children

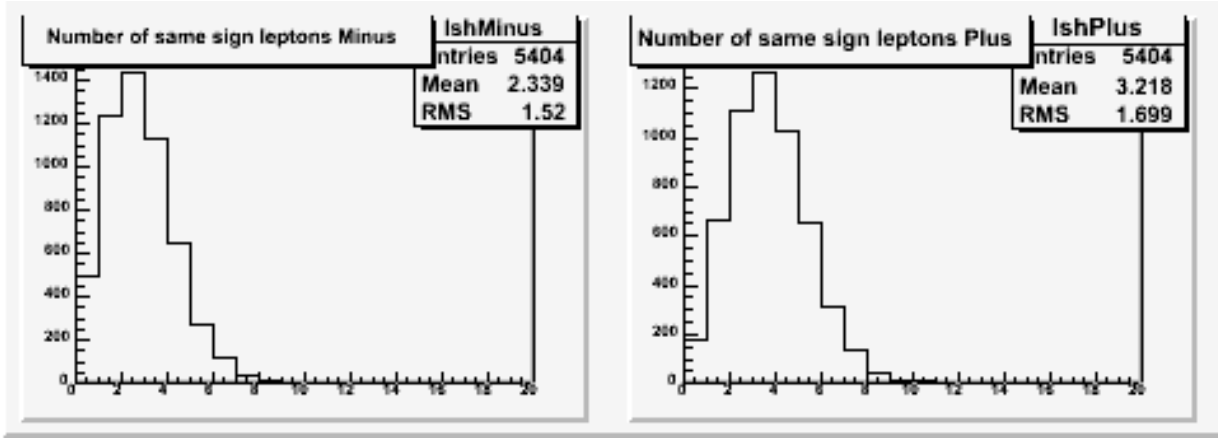
McEventCollection_p4_GEN_EVENT

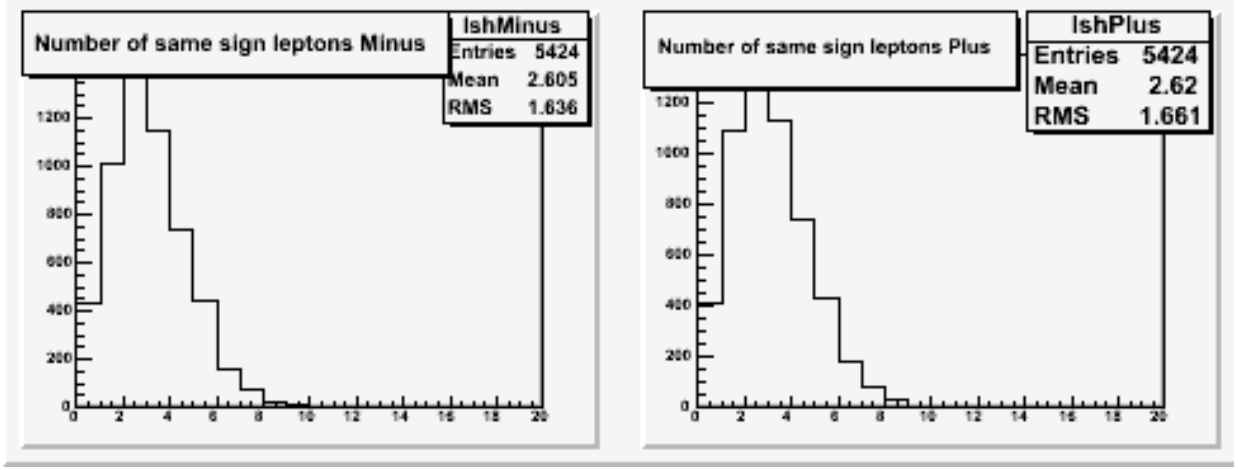
- Reconstructed mass of third and fourth jet (as from the theory paper)
  - Mass way higher
  - High jet multiplicity (too high)
  - Run with cone 0.7
    - multiplicity still high

JetCollection_tlp5_Cone4TruthJets

  - Select jets matched to b's in DeltaR and plots their reco mass
    - Mass structure observed.
  - TruthJet multiplicity and removing the "slepton-jets"

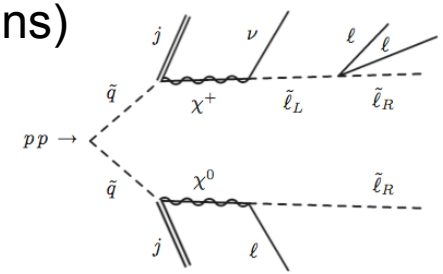
Lepton multiplicities



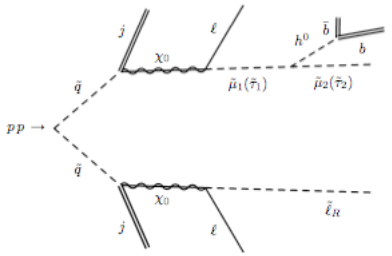


Number of same sign leptons (flavor blind)

All-Processes
The asymmetry is expected
(three-body decay of sleptons)

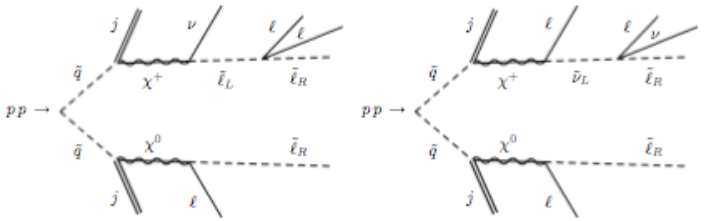


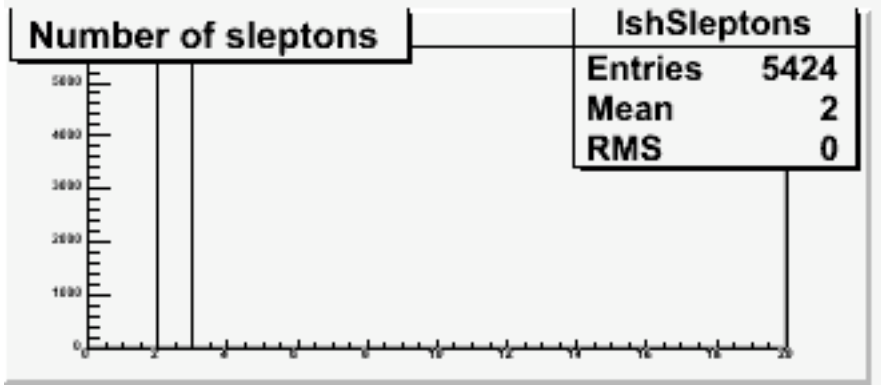
Higgs-only

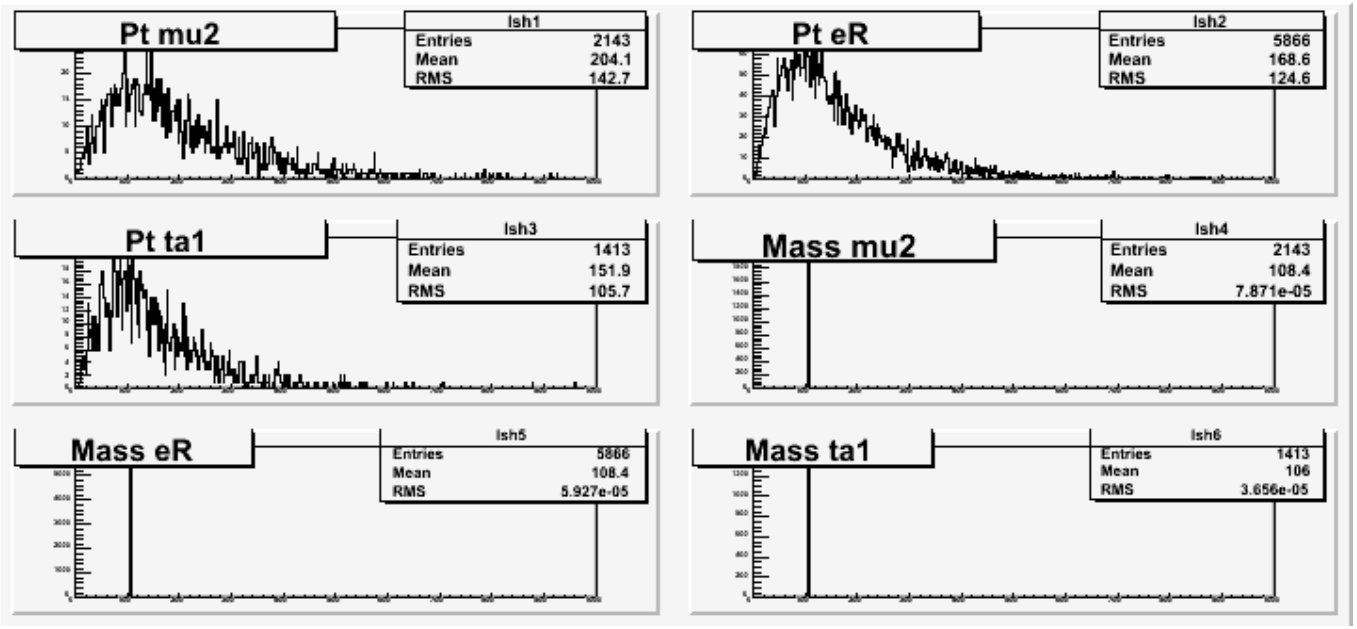


Sleptons multiplicity

Two for each event





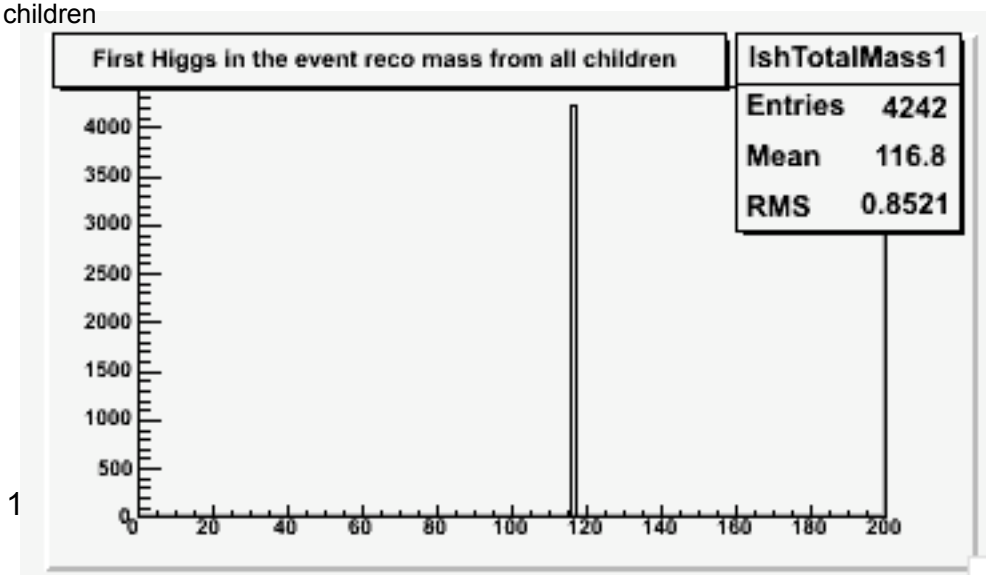


All Processes
(eR is not present in events with Higgs production)

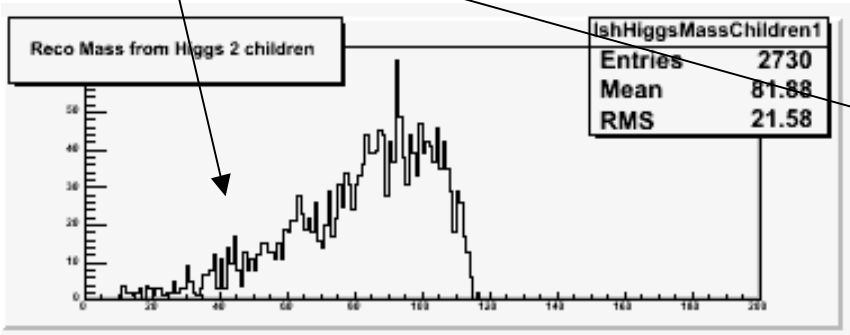
Reconstructed Higgs Mass

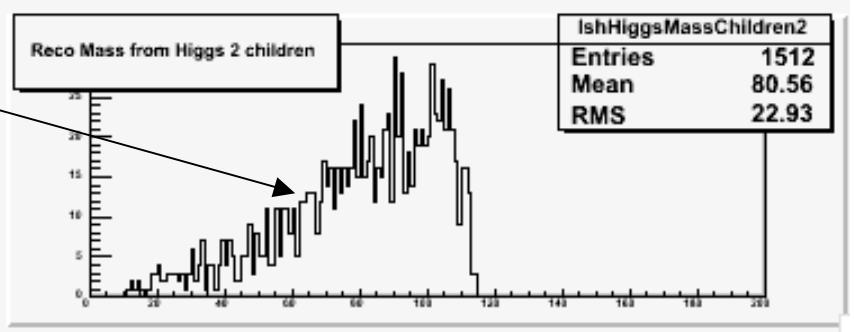
Select a Higgs and check for its children to select a bbar pair:

- ===Event number 5424 Higgs has 13 children with ID and status of the children
- ID = 5 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = -2 status = 2
- ID = 2 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = 21 status = 2
- ID = -5 status = 2
- ====Event Number 5424 After Loop on nhep, Number of Higgs in this event is 1

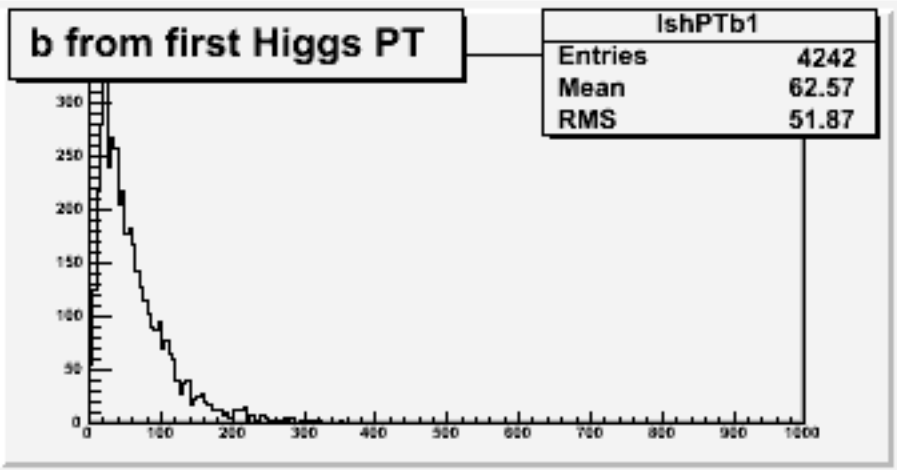


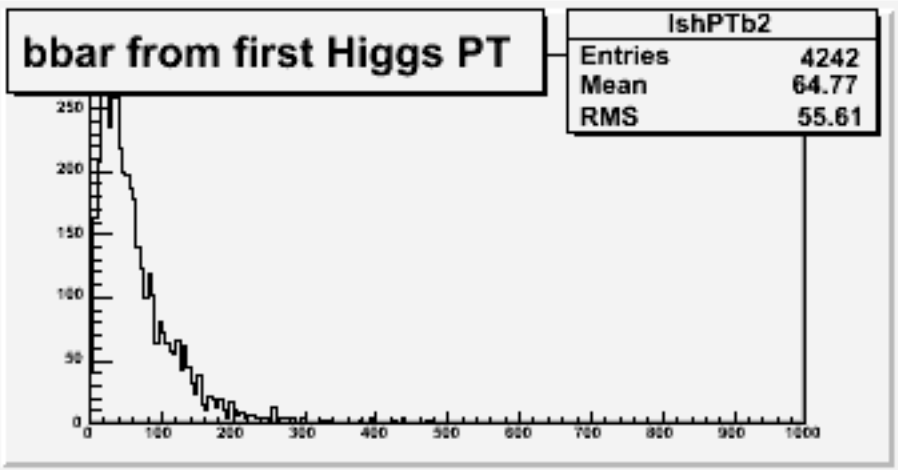
Low tail due to radiation

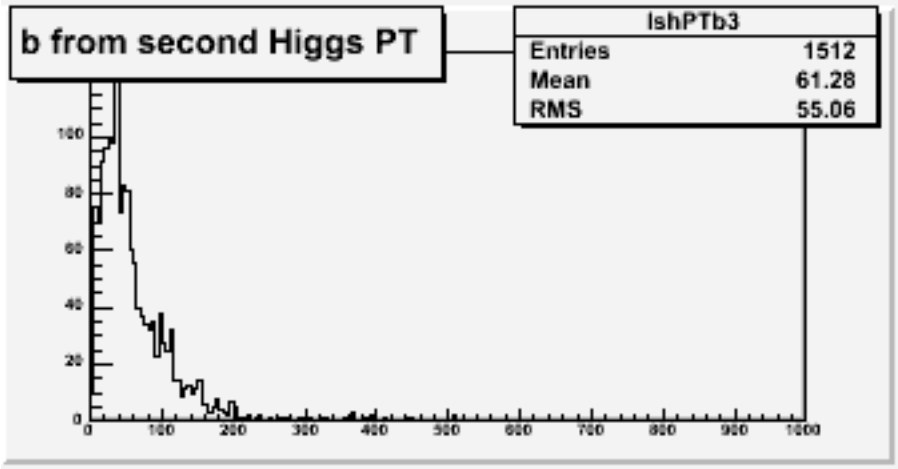


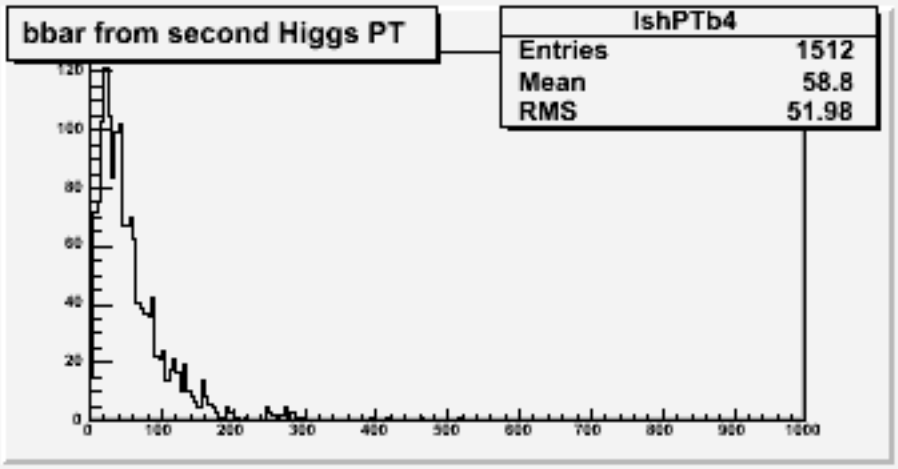


Pt of b partons



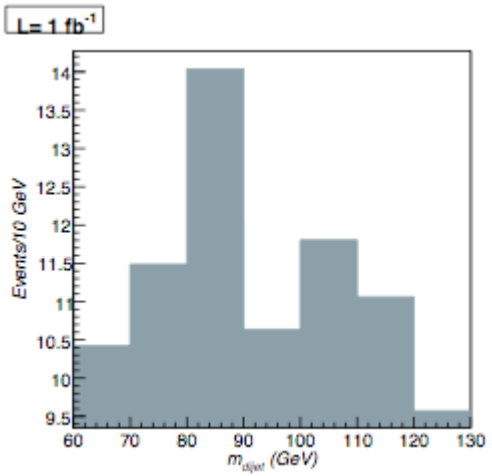


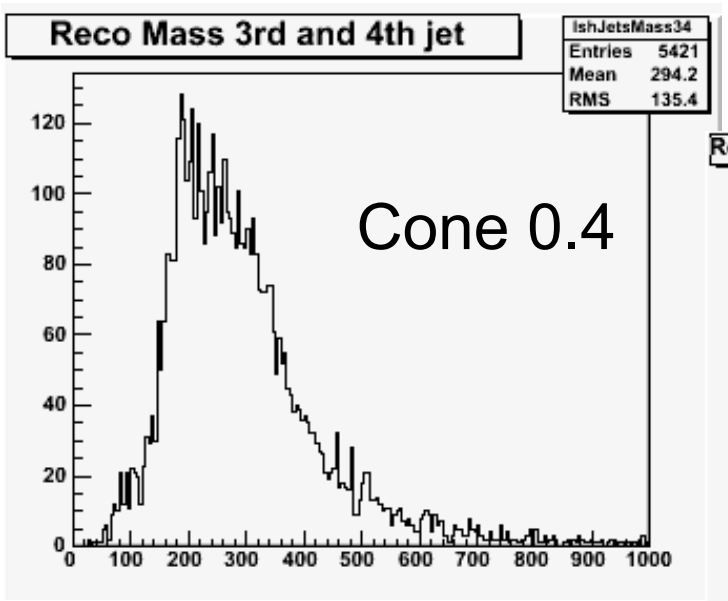


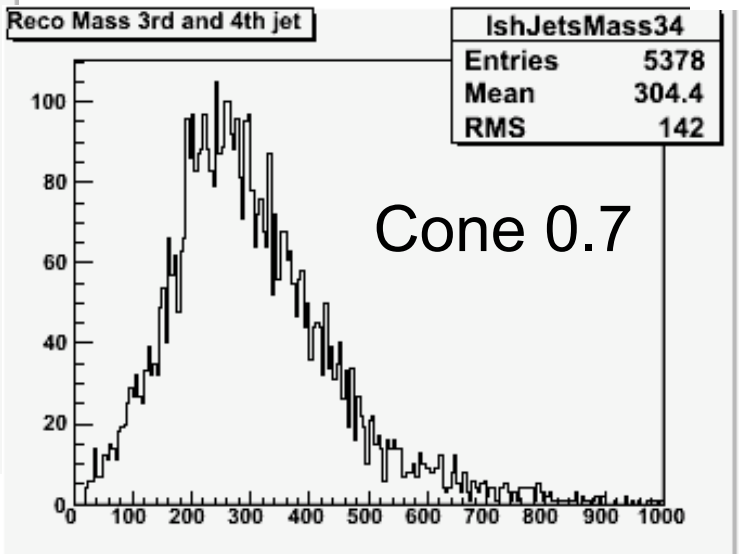


Jets and Higgs mass

In the theory paper, the authors select events with 2 sleptons and reconstruct the mass of the 3rd and 4th jet, with PT > 25
Clear Z and Higgs peaks are observed (easy!)
We tried to reproduce the result….







Obviously something is wrong…

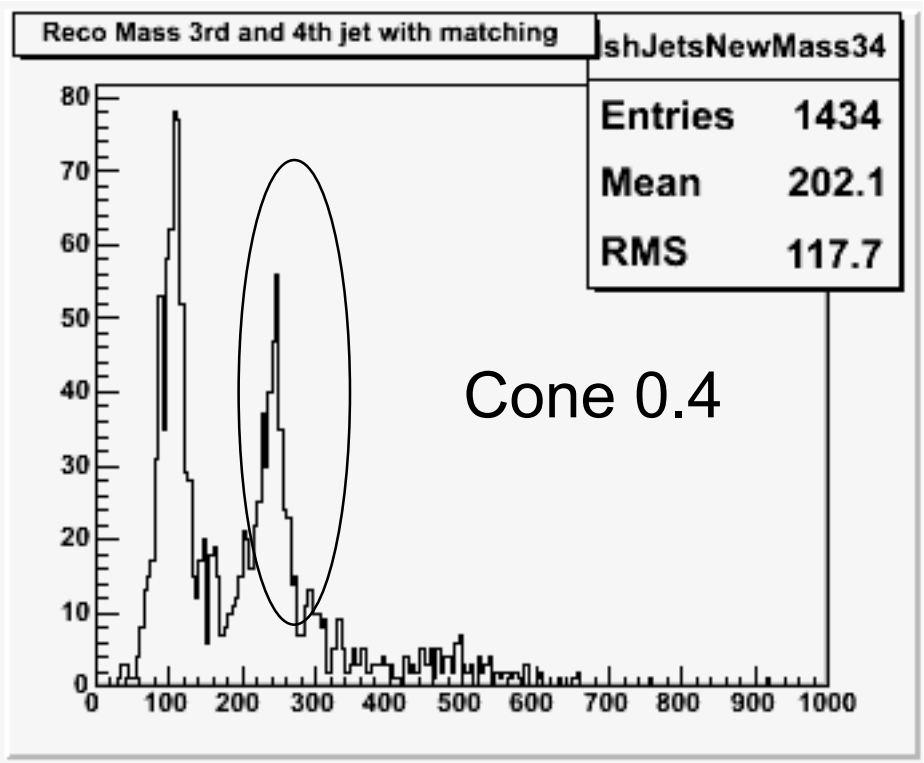
Mass combination of jets matched to b-bbar pair

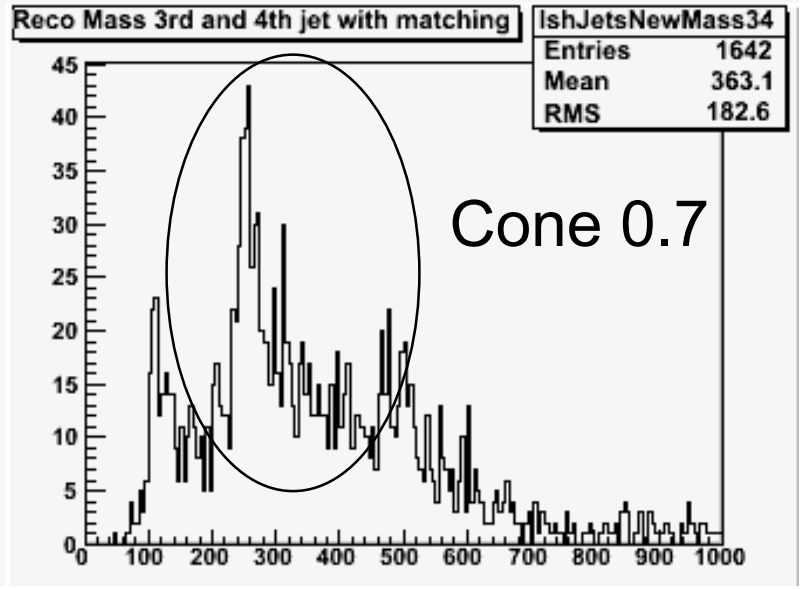
We decided to select jets by associating them to the b-partons;

Events are selected where is only 1 Higgs (for sake of simplicity) decaying into bbar

The jets are associated to the bbar via DeltaR

The mass distributions were even more puzzling…





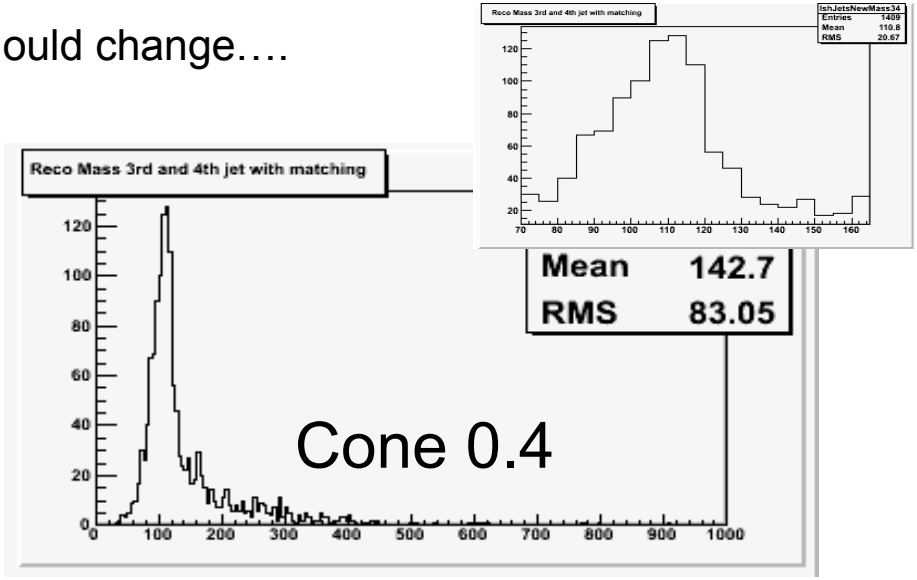
What is the second peak??

The second peak…

The second peak is at the mass of the slepton….Can it be that TruthJet reconstruction picks the slepton and makes a jet of it ?

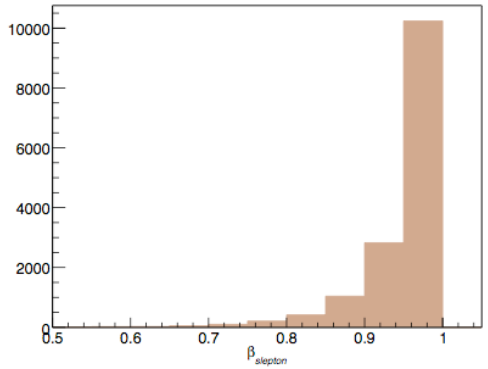
- Because of the boost the "slepton jet" is very close to the b's from the Higgs and gets picked as the closest jet to the b's.
- Solution: remove the 2 jets closest to the 2 sleptons in the event and do the Higgs mass reconstruction with the remaining jets using the 2 closest to the b's from the Higgs..
- Even better: we modified the stable truth collection before running JetTruthAlgorithm to remove the sleptons from the list of final state particles to be used for jet reco;
  - The jets multiplicity and reco Higgs mass should change….
  - And they do!!

Lesson learned… be careful at how exotic SUSY particles are used in FastSim or TruthAlgs….



Sleptons as Leptons

- In the leptogenic scenario the sleptons will behave like CHAMPs, ie slow moving particle crossing the detector with MIP-like signature.
- A challenge in this case will be the correct assignment of bunch crossing;
- Efficiencies to correctly assign the slow-moving particle to BC decreases with β : for $0.8 < \beta < 1.0$ the efficiency is ~80-100%*
  - Most of our sleptons will have $\beta > 0.8$
- Shlomit Tarem and her group provided us with a modified setup for simulation and reconstruction for this process in FullSim (EPJ 62,2 (2009) p281)
- We are also using FastSim samples, forcing the heavy sleptons to behave like muons
  - We can do it because we are not interested in the slepton mass reconstruction but only Higgs
- What trigger to use? Work in progress…

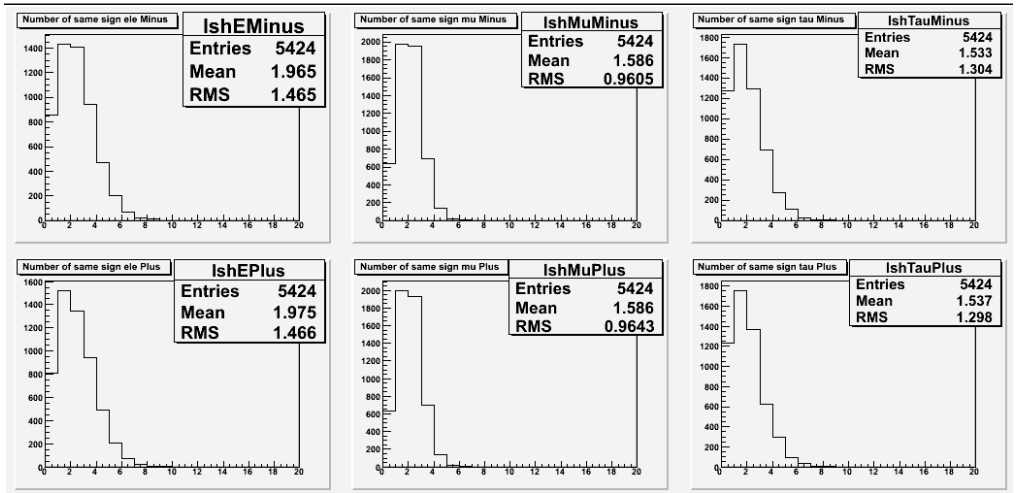


* arXiv:0901.0512

FullSim and FastSim studies

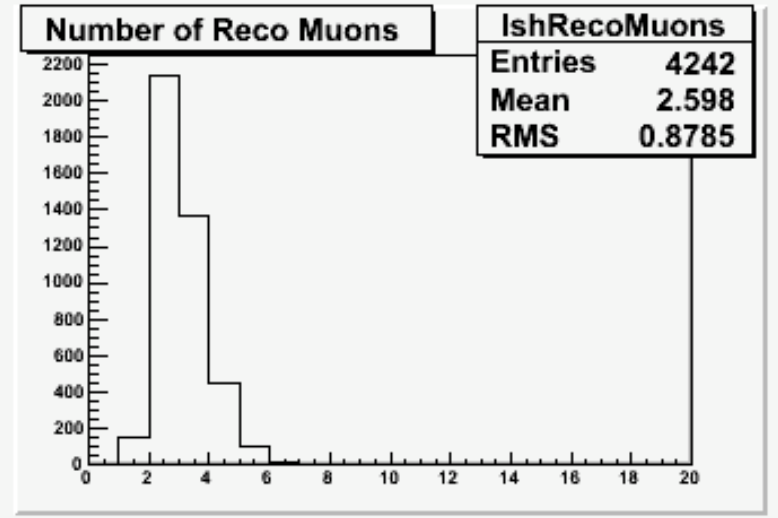
- FullSim was ran following the prescriptions in EPJ 62,2 (2009) p281 (Trigger and Reconstruction for heavy long lived charged particles with the ATLAS detector)
- FastSim was run with the help of S. Chekanov, using the assumption that our sleptons would behave as muons ($\beta > 0.80$)
- Limited samples are available in AOD format
  - ElectronContainer
  - MuonContainer
  - JetContainer

FastSim: Lepton multiplicities

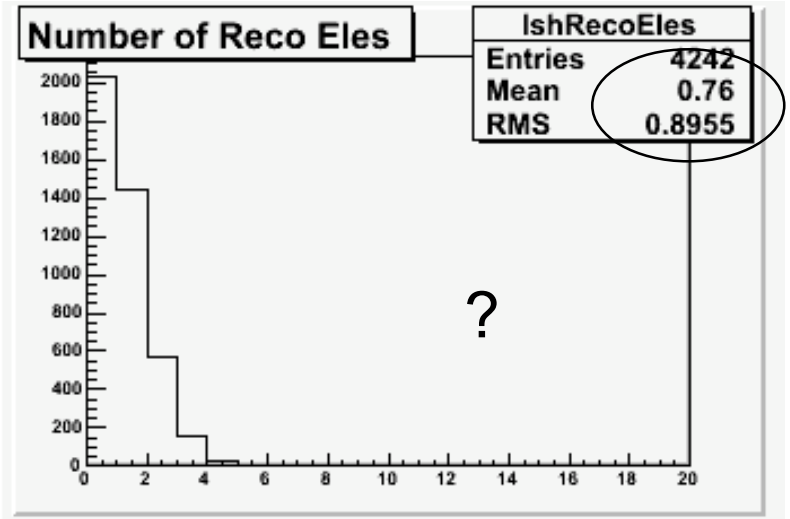


FastSim: parton level

muon multiplicity increases by construction

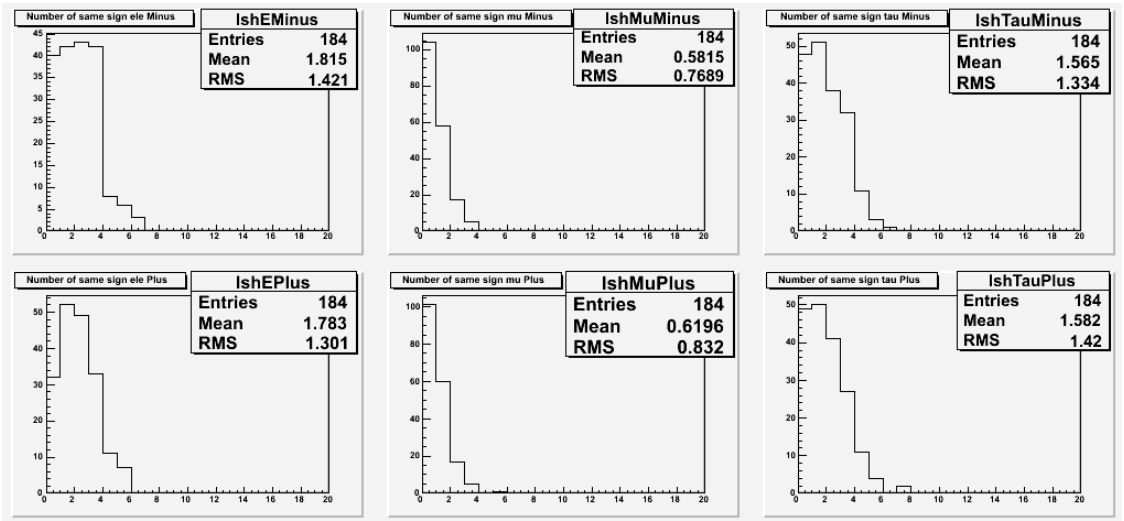


MuonContainer_p5_AtlfastIsoMuonCollection

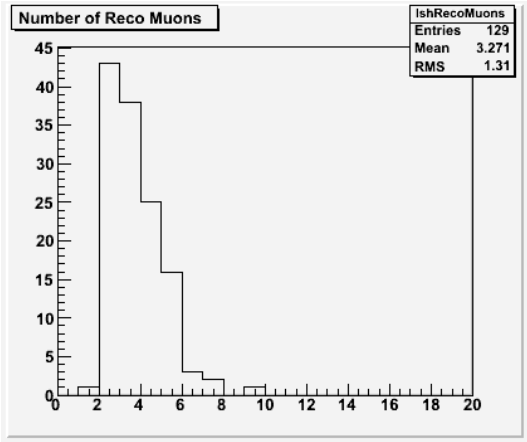


ElectronContainer_p2_AtlfastElectronCollection

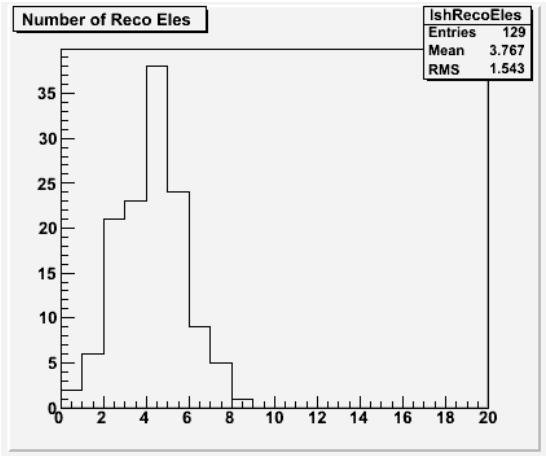
FullSim: Lepton Multiplicities



McEventCollection_p4_GEN_AOD



MuonContainer_p5_MuidMuonCollection



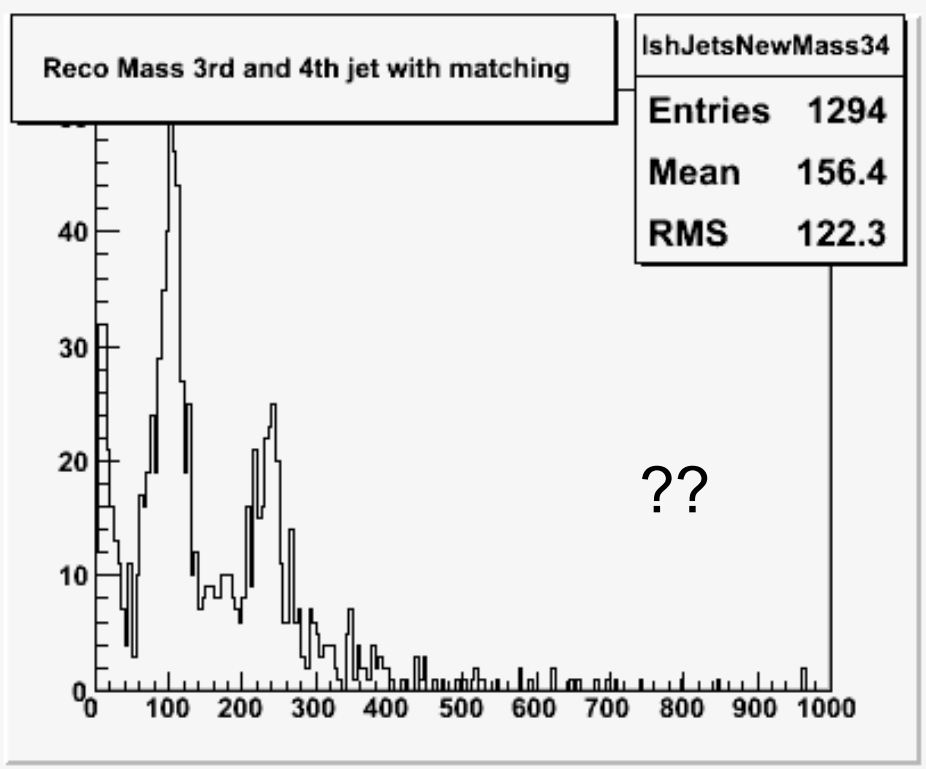
ElectronContainer_p2_ElectronAODCollection

We are not looking at reconstructed τ's yet

What about lepton ID cuts?

b-tagged jets

FastSim does not have b-tagging info, jets are "tagged" using a DeltaR match between jets and b-partons
The jets selected in this way are used to form and invariant mass



Second peak, strangely at the slepton mass.. But where does it come from?

There should not be sleptons to be used by JetReco (they have been swapped with muons)

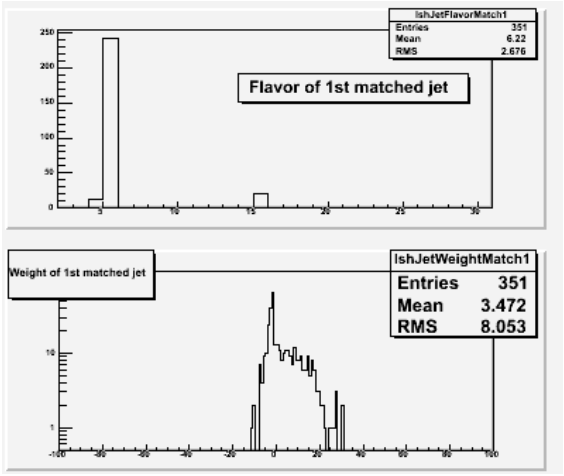
More investigation underway…

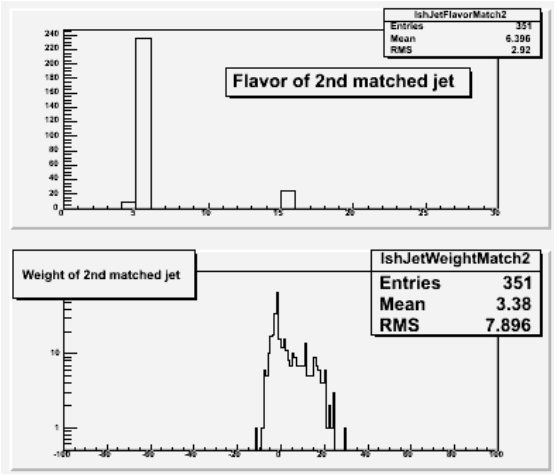
B-tagged jets

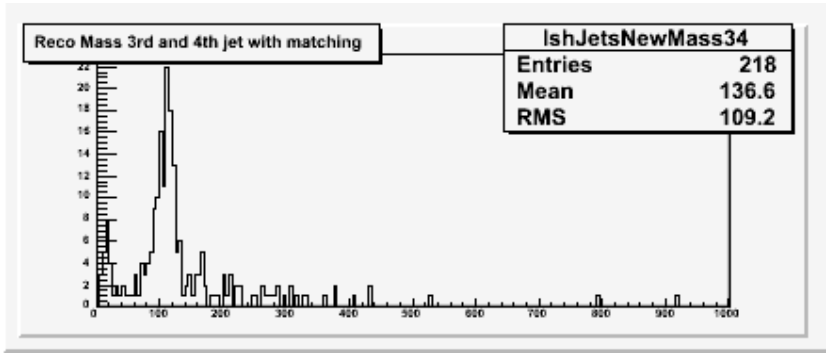
FullSim has b-tag info

```
getFlavourTagWeight(); // weight for IP3DSV1
This is an high-end tagger, combination of impact parameter and
secondary vertex info
```

Jets are still matched to b-partons - then the flavor/weight information is checked - fairly good purity



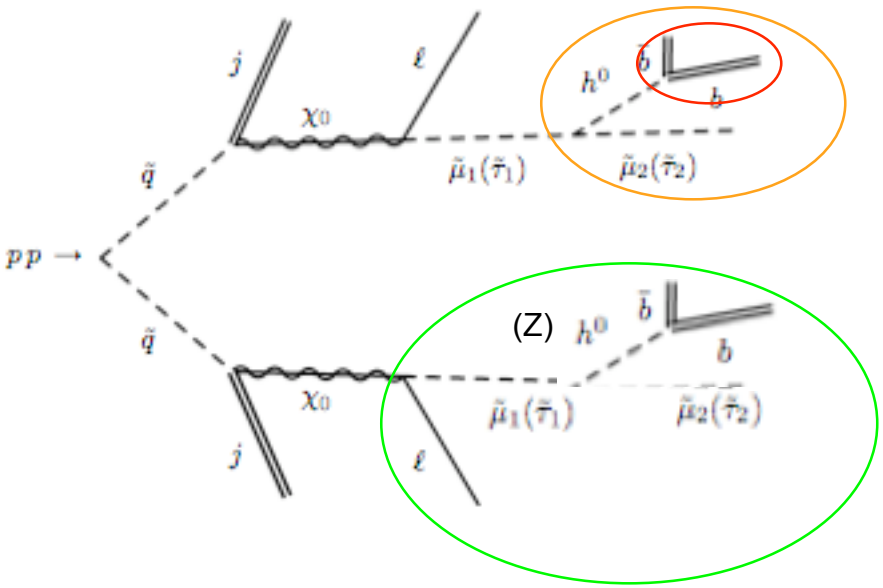


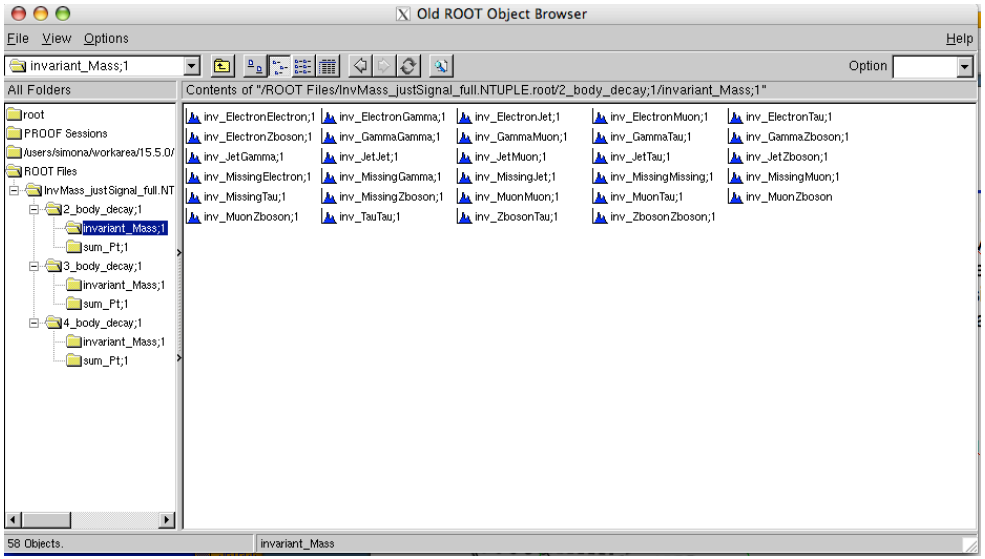


The reconstructed mass looks good, no second peak

InvMass tests

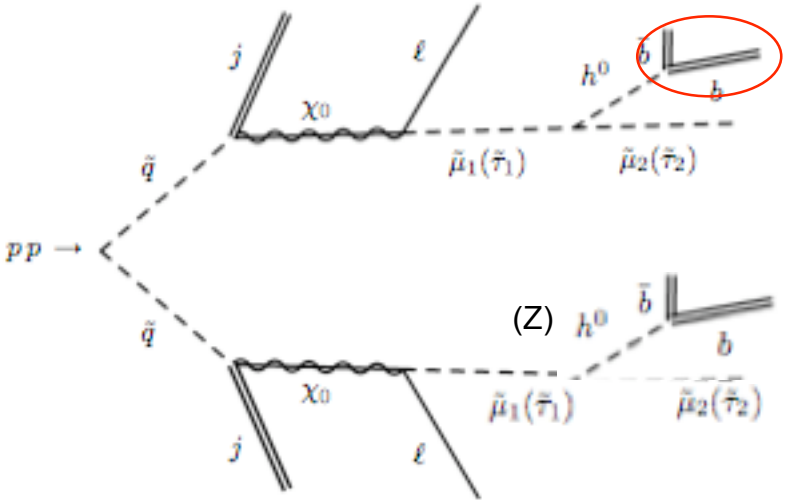
InvMass is a program that has been written at ANL to execute general searches using high E_T reconstructed objects (J.Boomsma & S.Cheknov)
It takes as input ntuple created by the PromptGamma package, which creates ntuples with up to 7 particle types stored in AOD/DPD, after using selection cuts defined by the user and performing an overlap removal. The package is now optimized for photon searches and we took it "as-is".

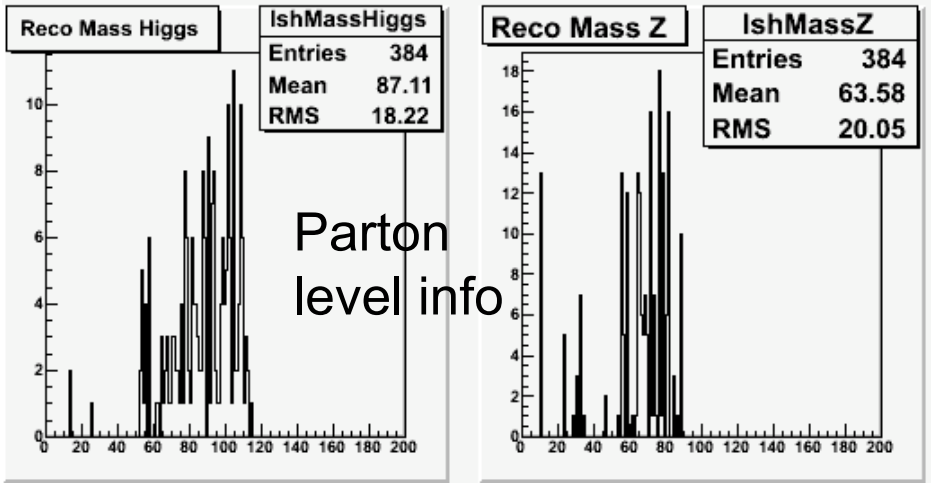


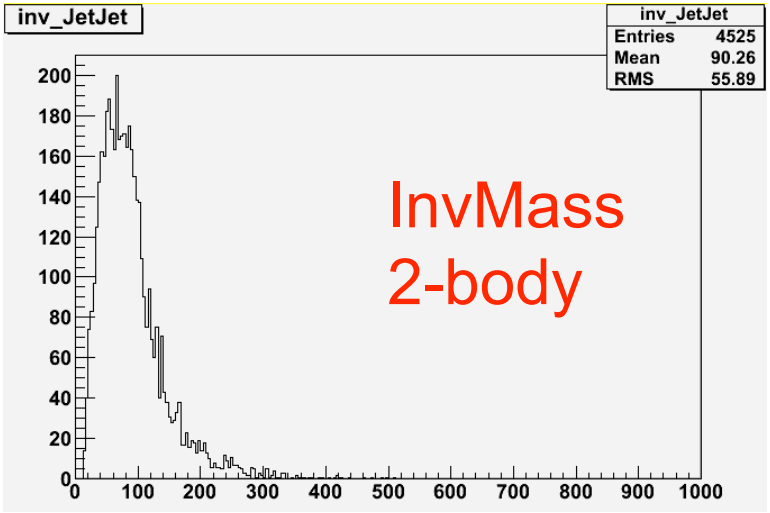


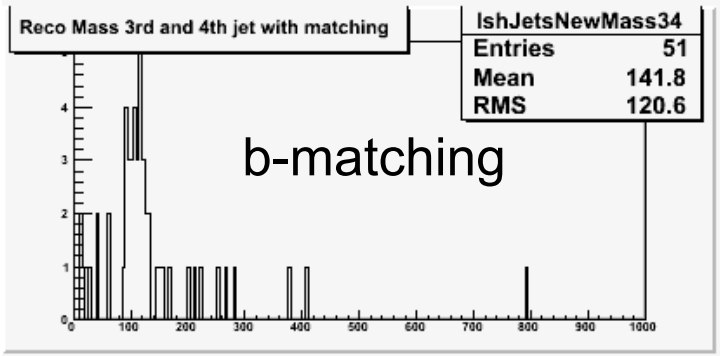
2-body JetJet
3-body JetJetMu
4-body JetJetMuMu(tau)

FullSim 2-body

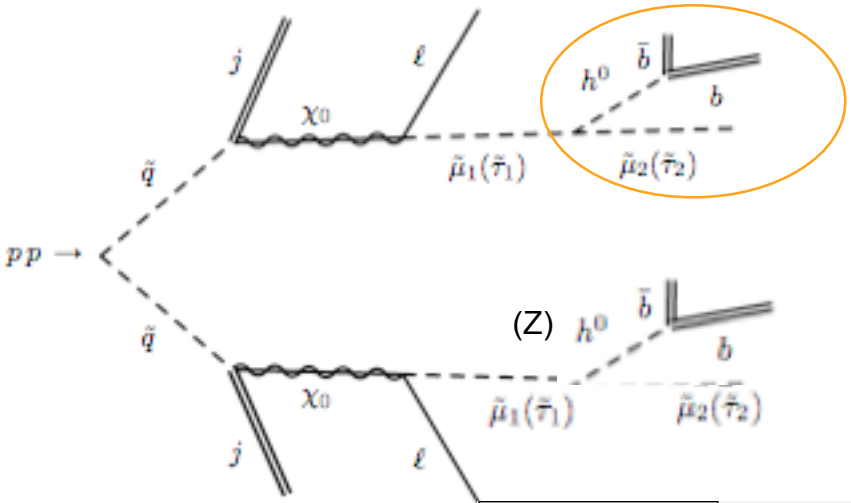


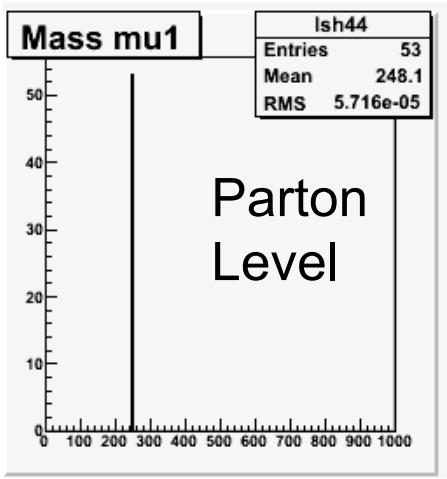


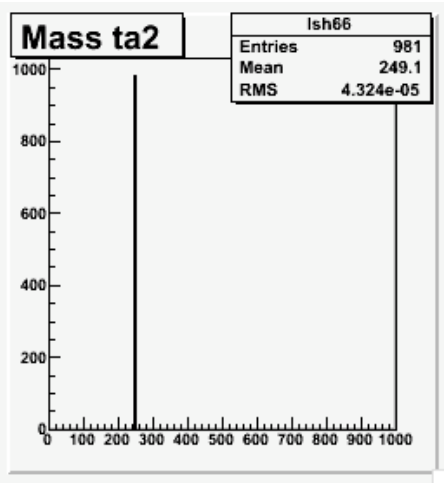


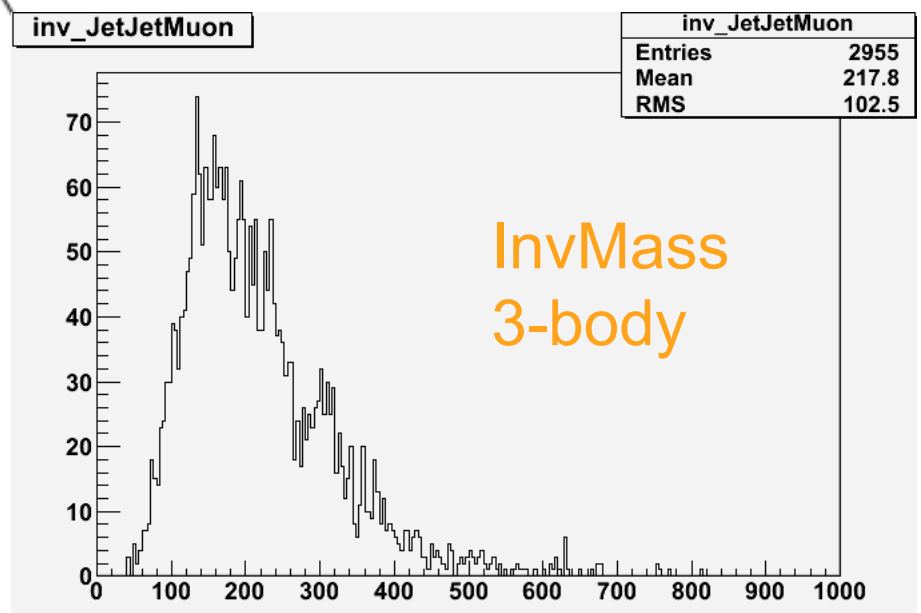


FullSim 3-body

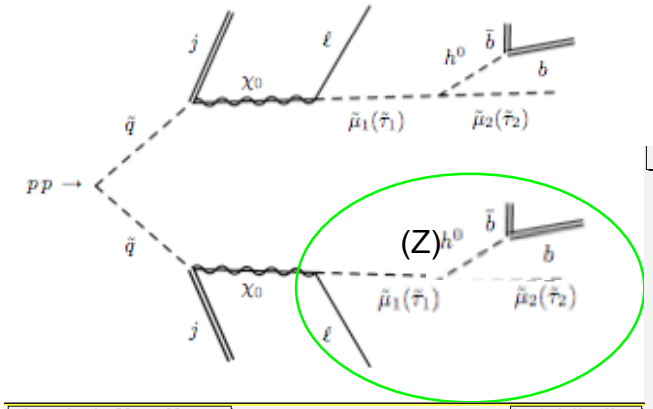


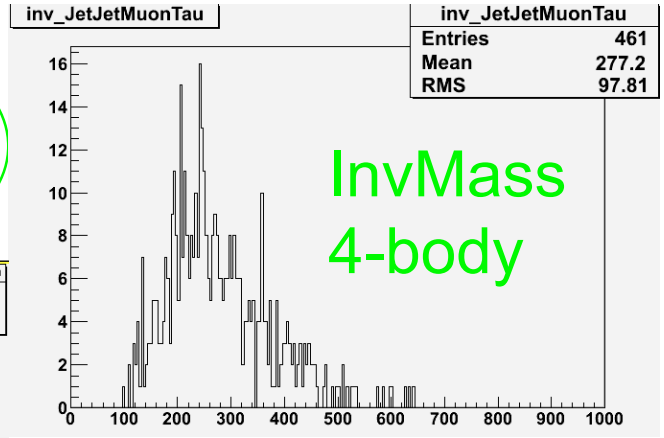


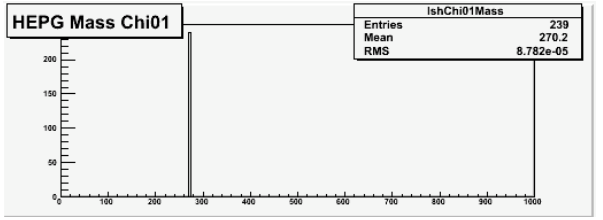


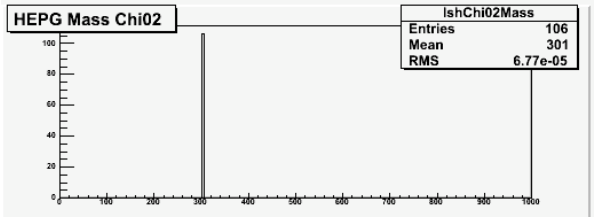


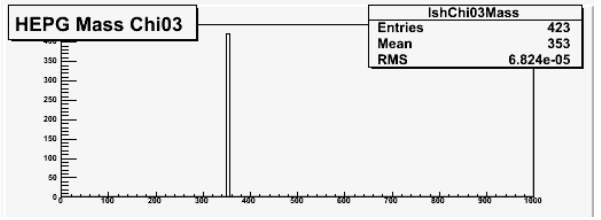
FullSim 4-body

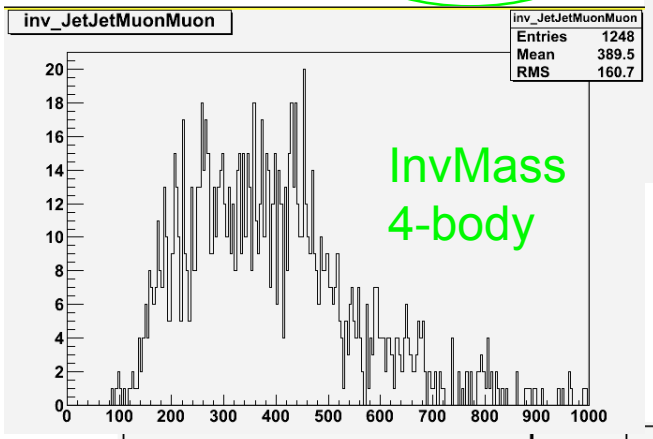


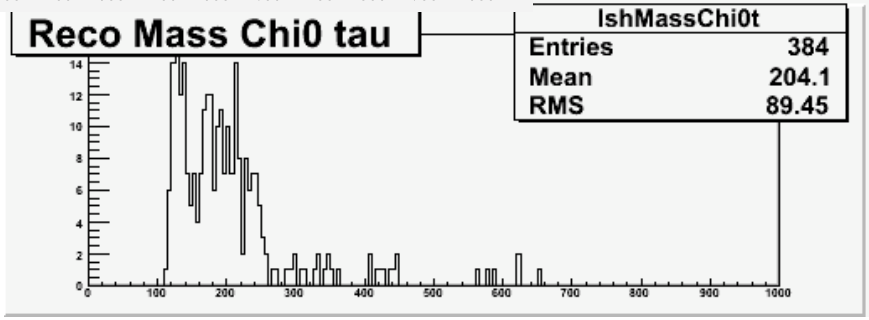


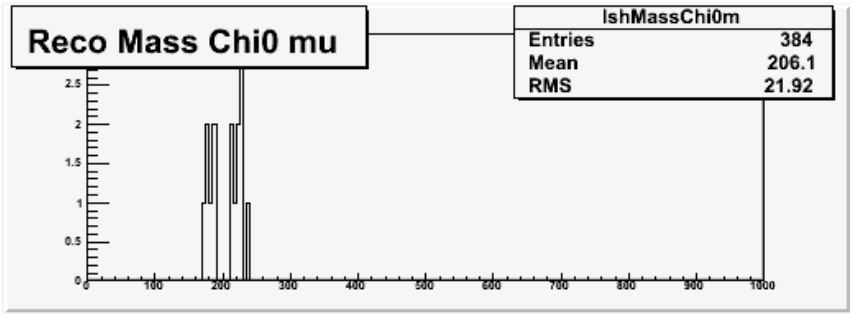












Conclusions

- We are setting up the framework for an analysis aimed at searching for Higgs produced in association with heavy sleptons, jets and leptons
  - H→bb, virtually no background
- We tested the parton level characteristics of the sample
  - A formal request for MC production was submitted in Dec 2009
- We are starting to test reconstructed quantities
  - FullSim vs FastSim comparison..
  - Object Identification criteria..
    - It would be useful to have more info on lepton ID, tau reco and jet reco easily available here - maybe some working group?
  - B-tagging..
- InvMass analysis framework used to setup a signature-based analysis
- Work in progress..
  - Tau reconstruction
  - Trigger
  - …